METHOD AND APPARATUS FOR RECORDING AND REPRODUCING DIGITAL DATA

Inventor: Sehat Sutardja

Cross-Reference to Related Application

This application claims priority under 35 U.S.C. § 119(e) on U.S. Provisional application serial No. 60/211,874, entitled "Method And Apparatus For Recording And Reproducing Digital Data, " filed June 14, 2000, the contents of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to an apparatus for recording and reproducing digital data. More particularly, the present invention relates to a media player/recorder, having a miniature hard disk drive for storing the digital data.

Description of the Related Art

Fig. 1 is an example of a conventional MP3 player. MP3 player includes an interface 106, nonvolatile solid state memory 102, an decoder 110, a digital-to-analog (D/A) converter 147, an audio output 116, a key pad 108, a display 112, a controller 104, RAM 144 and ROM 145.

Controller 104 controls the operation of the MP3 player in accordance with a set of programmed instructions. Programmed instructions for controller 104 are stored in nonvolatile memory or ROM 145, and RAM 144 is provided as the working memory for controller 104

Typically, MP3 data, which is a digital compressed format representing music data, is initially stored on a personal computer 50 and is subsequently transferred to the MP3 player via interface 106, under control of controller 104. The MP3 data is stored in nonvolatile solid state memory 102. Interface 50 can implemented by a standard parallel port, serial port, USB and the like. Nonvolatile solid state memory 102 may be implemented as flash memory. Generally, for a music quality recording, a nonvolatile solid state memory having 64 Mbytes can store about 1 hour of music.

Flash memory provides the capability of retaining the stored digital data even when the MP3 player is powered down. Once the digital data has been transferred to the MP3 player, it no longer needs to be connected to personal computer 50, and the MP3 player can play back the MP3 data autonomously from personal computer 50.

Decoder 110 functions to decode and decompress the MP3 data file stored in nonvolatile solid state memory 102. Decoder 110 decompresses the MP3 music file in accordance controller 104 according to the MP3 format, and decodes the decompressed music file into a bit stream form. The bit stream is then converted into analog form by digital to analog converter 147 for connection to a speaker, earphone and the like. A decoding program for the MP3 decoder function is stored in the ROM 145 and loaded to RAM 144 by controller 104 as required.

The MP3 player comprises a keypad 108 for allowing user control and interaction with the MP3 player. Such control may include power on/power off, music selection and volume. The MP3 also comprises a display 112 for displaying characters or graphics, such as a battery indicator, a play mode indicator, a volume indicator, available memory size and the title of the music being played.

One disadvantage of the conventional MP3 player is that the amount of music data stored in the MP3 player is limited by the amount of flash memory installed in the MP3 player. Flash memory is expensive which inapposite to such a portable consumer electronic device. Additionally, by incorporating a large amount of flash memory, there is an increase in required energy to supply the MP3 player. This results in a shorter operating time or and increase in weight for additional batteries to supply this increase in required energy. This is also disadvantageous for a portable device. Moreover the decoding algorithm is either store in the ROM or flash memory. When the decoding algorithm is stored in ROM, the ROM needs to be changed to update, revise or change the decoding algorithm. Moreover a larger ROM is required if multiple algorithms are stored therein. Similarly, if multiple algorithms are stored in flash memory, a larger flash memory is required, which increases cost and energy consumption.

Summary of the Invention

According to a first aspect of the present invention, a media player/recorder comprises a disk drive to store compressed media data, and a processor to retrieve the media data stored in the disk drive. A memory is provided to store the media data

retrieved by the processor. The processor decompresses the media data stored in the memory, and an output circuit outputs the decompressed media data from the processor.

According to a second aspect of the present invention, the memory comprises a dynamic access memory.

According to a third aspect of the present invention, the media player further comprises an interface responsive to the processor to communicate with an external device.

According to a fourth aspect of the present invention, the processor comprises a digital signal processor to control the disk drive and to decompress the media data stored in the memory.

According to a fifth aspect of the present invention, the processor comprises a single integrated circuit comprising a digital signal processor to control the disk drive and to decompress the media data stored in the memory, a storage controller is responsive to the digital signal processor, and a read channel reads data from the disk drive and responsive to the storage controller.

According to a sixth aspect of the present invention, the digital signal processor comprises a decoder to decompress the media data stored in the memory.

According to a seventh aspect of the present invention the disk drive stores a process for decompressing compressed data for a selected compression format.

According to an eleventh aspect of the present invention, the digital signal processor determines a compression format of the media data stored in the memory, wherein the process for decompressing compressed data is retrieved from the disk drive in accordance with the determined compression format, and wherein the decoder decompresses the media data in accordance with the retrieved process.

According to an twelfth aspect of the present invention, the media data is transferred from the external device through the interface for storage on the disk drive.

According to an thirteenth aspect of the present invention, the media player further comprises an input circuit to receive media data, wherein the digital signal processor comprises an encoder to compress the received media data, and wherein the compress media data received by the input circuit is stored on the disk drive.

Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

In the drawings wherein like reference symbols refer to like parts.

Fig. 1 is a block diagram of a conventional MP3 player;

Fig. 2 is a block diagram of a first embodiment of a media player/recorder in accordance with the present invention;

Fig. 3 is a more detailed block diagram of the media player/recorder of Fig 2;

Fig. 4 is a block diagram of a second embodiment of a media player/recorder in accordance with the present invention;

Fig. 5 is a more detailed block diagram of the media player/recorder of Fig 4;

FIG. 6 shows an exemplary data format of a magnetic disk having a plurality of concentric tracks comprised of a plurality of user data sectors and embedded servo data sectors;

FIG. 7 is a schematic representation of memory 202;

FIG. 8 is a memory map of memory 202;

FIG. 9 is flow chart of an energization/deenergization procedure according to a first embodiment of the present invention;

FIG. 10 is flow chart of an energization/deenergization procedure according to a second embodiment of the present invention;

FIG. 11 is flow chart of an energization/deenergization procedure according to a third embodiment of the present invention; and

FIG. 12 is flow chart of an operating procedure according to the present invention.

Description of the Preferred Embodiments

The present invention is directed to a media player/recorder apparatus, and in particular one that is portable. As used herein the term media player/recorder apparatus refers to an audio and/or video play back and recording apparatus. In

general, audio and/or video analog data is first digitized and compressed using one of a variety of formats and recorded in the media player/recorder for subsequent play back thereby. During playback the digitized data is decompressed and converted to an analog signal. Additionally while the preferred format for compressing audio data is known as MP3, the present invention is independent of the compression format and not limited to MP3. The compression format therefore may include any other suitable compression format, such as, by way of example, EPAC ™, QDesign Music playback, AAC, Liquid Audio, MS Audio, Dolby Digital, and the like.

Referring to Fig. 2 there is shown the first embodiment of media player/recorder of the present invention. The media player/recorder includes an interface 206, memory 202, a processor 300, an output 216, a keypad 208, a display 212, a storage device (the storage device may utilize, for example, a magnetic media (such as a hard disk drive), magneto-optical media, an optical media (such as a CD ROM, CDR, CDRW or the like), and the like) such as, a disk drive 230, a preamp 232 and a voice coil motor (VCM) 234.

The operation of the media player/recorder is as follows. Operation of the media player/recorder is controlled by the user through keypad 208. Status of the media player/recorder is provided to the user by display 212.

Media data, which was previously digitized, may be obtained (downloaded) from a personal computer, network appliance, local area network, Internet 50 and the like. Such external devices communicate with the media player/recorder via interface 206, which is controlled by processor 300. Interface 206 may be implemented, for example, as a parallel interface, serial interface, USB, Ethernet connection, IEEE 1394 (a.k.a. Firewire), infrared interface, IEEE 802.15, Bluetooth™ and the like. Again the present invention is independent of the interface selected. Media data is then stored on the storage device such as, disk drive 230 in accordance with processor 300. Disk drive 230 is preferably a miniature drive with a capacity of 1 Gbyte of data storage, which is particularly suitable for a portable device. Of course, any other appropriate sized disk drive may be employed.

Alternatively, media data may be obtained directly from an external analog source, such as a microphone or video camera, connected to input 214. Input 214 takes the input signal from external device and sets the analog signal to an appropriate level. The analog signal is then converted to a digital signal and compressed using a

selected format by processor 300, as will be described hereinbelow. The compressed digital data is similarly stored on disk drive 230.

When the user chooses a selection of media data to be played back with keypad 208, processor 300 powers up disk drive 230 and retrieves the selected data which is then transferred to memory 202. It is noted that the powering up of the device is done in a sequential manner so as to minimize energy consumption of the device. A more detailed description is provided below.

Memory 202 comprises a solid state memory, such as, for example dynamic random access memory (solid state memory), flash memory, EEPROM, or the like. It is not necessary for memory 202 to be nonvolatile since the media data is stored in a nonvolatile manner on storage device or disk drive 230. The quantity of solid state memory required is less than is required in a conventional MP3 player. The quantity of solid state memory contemplate is about 2 Mbytes, which is sufficient to store about 2 minutes of MP3 data. Of course, as will be appreciated by one of ordinary skill in the art, when dealing with video data, more solid state memory may be required. The amount of solid state memory supplied is selected to minimize energy consumption.

After the selected data is stored in memory 202, disk drive 230 is then powered down. In this manner, during playback disk drive 230 is only powered up only during the transfer of the selected media data from disk drive 230 to memory 202, which results in lower energy consumption. A more detailed description of the powering down of disk drive 230 is provided herein below. The media data is retrieved from memory 202. Processor 300 determines the format of data compression from the retrieved data. Disk drive 230, also stores the data compression/decompression algorithms. The data is decompressed in accordance with the determined format and converted to an analog signal by processor 300. The analog signal is set to an appropriate level by output circuit 216. If the analog signal contains audio data, output circuit 216 is connected to a speaker, headphone and the like for playback, and if the analog signal contains video data, output circuit 216 is connected to a display device for playback.

Additionally, media data recorded on disk drive 230 or stored in memory 202 may be transferred (uploaded) to a personal computer, network appliance, local area network, internet 50 or another media player/recorder through interface 206 under the control of processor 300.

FIG. 3 is a detailed block diagram of processor 300. Processor 300 is preferably implemented as a single integrated circuit. A media playback/recorder apparatus having a processor implemented as a single integrated circuit can be fabricated at lower cost and have lower energy consumption. Alternatively, processor 300 may be implemented by discrete components. Processor 300 comprises a read channel 341, storage controller or hard disk controller 342, digital signal processor/microprocessor unit (DSP/MPU) 343, random access memory (RAM) 344, a non volatile memory such as read only memory (ROM) 345, digital to analog converter (DAC) 346 and analog to digital converter (ADC) 347. DSP/MPU 343 comprises servo controller 349 and Codec 348. In the preferred embodiment, DSP/MPU 343 is implemented as a single integrated circuit. In another embodiment, MPU may be implemented as one integrated circuit and the DSP may be implemented as another integrated circuit.

It is noted that DSP/MPU 344 may comprise a microprocessor unit, a digital signal processor or combination thereof. ROM 345 stores programmed instructions for processor 300 and DSP/MPU 343 to control the operation of both the disk drive 230 (and associated circuitry) and the signal processing of the media data. RAM 345 is provided as a working memory for DSP/MPU 343. For each of the various compression formats discussed above, the decompression and compression algorithms for Codec 348 are stored on disk drive 230. Storing the decompression and compression algorithms on disk drive 230 minimizes the size of ROM 344 and its energy consumption. Additionally, this feature allows future compression and decompressions formats to be easily implemented for the media player/recorder.

Prior to discussing the operation of processor 300, reference is made to Fig 6. FIG. 6 shows an exemplary data format of a magnetic media used, in disk drive 230, comprising a series of concentric data tracks 13 wherein each data track 13 comprises a plurality of sectors 15 with embedded servo wedges 17. Servo controller 349 processes the servo data in servo wedges 17 and, in response thereto, positions the read/write head over a desired track. Additionally, servo controller 349 processes servo bursts within servo wedges 17 to keep a disk head of disk drive 230 aligned over a centerline of the desired track while writing and reading data. Servo wedges 17 may be detected by the discrete time sequence detector implemented in DSP/MPU 343. It is important to note that DSP/MPU 343 is utilized only during the time period for detecting servo wedges 17, during other periods DSP/MPU 343 is available to perform other functions as described below, such as signal processing for media data playback

and recording. By using only one DSP rather than two, the cost of fabrication can be reduced and the amount of energy consumption can also be reduced.

As described above, the powering up of the device is done in a sequential manner so as to minimize energy consumption of the device. More specifically, the mechanical or motor portions of the storage device are energized first. After the motor reaches operating speed, VCM 234 is energized, followed by the energization of read channel 341 and HDC 342.

The operation of processor 300 is as follows. DSP/MPU 343 controls the entire operation of the media player/recorder. DSP/MPU 343 is coupled to hard disk controller 342. When writing data to disk drive 230, hard disk controller 342 receives a write instruction and write data from DSP/MPU 343. The write data is temporarily stored in a cache memory (not shown) which is used as a buffer memory. Based on a clock from a clock generator (not shown), DSP/MPU 343 controls voice coil motor (VCM) and spindle motor 234 via servo unit 349. As a result, the magnetic head is moved to a desired track position on the magnetic disk by the head arm, and the magnetic disk is rotated at a rated rotational speed by the spindle, which is driven by spindle motor 234. The data is read from the cache memory and supplied to read channel 341 via hard disk controller 342. Read channel 341 encodes the write data under the control of DSP/MPU 343, and supplies the encoded write data to preamplifier 232. The magnetic head writes the encoded write data on the magnetic disk in accordance with a signal from preamplifier 232.

When reading data from the magnetic disk, hard disk controller 342 receives a read instruction from DSP/MPU 343. Based on a clock signal, DSP/MPU 343 controls voice coil motor and spindle motor 234 via servo unit 349. Hence, the magnetic head is moved to a desired track position on the magnetic disk by the head arm, and the magnetic disk is rotated by spindle motor 234.

The data read from the magnetic disk by the magnetic head is supplied to read channel 341 via preamplifier 232. Read channel 341 decodes the read data under the control of DSP/MPU 343, and generates read data. The read data are supplied from read channel 341 to hard disk controller 342 under the control of DSP/MPU 343, and are temporarily stored in the cache memory. The read data read from the cache memory are supplied to DSP/MPU 343 from hard disk controller 342.

As noted above, operation of the media player/recorder is controlled by the user through keypad 208, which is in communication with DSP/MPU 343. Status of the

media player/recorder is provided to the user by display 212 in accordance with DSP/MPU 343. When either uploading or downloading data, the media player/recorder is in communication with personal computer, network appliance, local area network, Internet 50. Otherwise the media player/recorder can be operated independently. The user selects the file to be downloaded from personal computer, network appliance, local area network, Internet 50 by way of keypad 208. Alternatively the user can select the file to be downloaded from the personal computer. DSP/MPU 343 controls the flow of data interface 206 and stores the data onto hard disk 230 in accordance with the method described above. When uploading data to personal computer, network appliance, local area network, Internet 50 the process is reversed.

To record data directly input into media player/recorder from an external analog source, the external device is placed in communication with input 214. Input 214 takes the input signal from external device and sets the analog signal to an appropriate level. The analog signal is then converted to a digital signal by ADC 347 of processor 300. Codec 348 of DSP/MPU 343 compresses the digitized data using a default compression format or one selected by the user by way of keypad 208. The default or selected compression program is transferred from hard disk 230 to RAM 344 and provided to Codec 348 for encoding. The compressed digital data is similarly stored on disk drive 230 under the control of DSP/MPU 343.

When the user chooses a selection of media data to be played back with keypad 208, DSP/MPU 343 powers up disk drive 230 and retrieves the selected data as described above. The retrieved data is then written to memory 202. After the selected data is stored in memory 202, disk drive 230 is then powered down by DSP/MPU 343. In this manner, during playback disk drive 230 is powered up only during the transfer of the selected media data from disk drive 230 to memory 202, which results in lower energy consumption. A single song stored in MP3 format may take approximately one second to retrieve from disk drive 230. The media data is retrieved from memory 202 by DSP/MPU 343 and the compression format is then determined.

If the decompression program has already been transferred to RAM 344, the program is provided to Codec 348. Otherwise the decompression algorithm is retrieved from hard disk 230 and transferred to RAM 344. The data is then decompressed by Codec 348 and converted to an analog signal by DAC 346. The analog signal is set to an appropriate level by output circuit 216. If the analog signal contains audio data, output circuit 216 is connected to a speaker, headphone and the like for playback, and

if the analog signal contains video data, output circuit 216 is connected to a display device for playback.

It is noted that the capacity of disk drive 230 is selected to hold a desired amount of media data, and the amount of solid state memory 202 is selected to minimize energy consumption. A disk drive having a capacity of 1 Gbyte can store approximately 30 hours of MP3 compressed music.

This section will described the power management control of the device by CPU/MPU 343.

Referring now to Figs. 3, 7 and 9. When the user turns on the media player and selects a file to be played (step 912), the various components of media player are powered up in a sequential manner so as to minimize energy consumption of the device. More specifically, the mechanical or motor portions of the storage device or disk drive 230 are energized first (step 914). After the motor reaches its operating speed (step 916), VCM 234, preamp 332, read channel 341 and HDC 342 are energized, since these components are only functional after disk drive 230 becomes operational. Energy would be unnecessarily expended if preamp 332, read channel 341 and HDC 342 were energized before disk drive 230 becomes operational. Therefore, VCM 234, preamp 332, read channel 341 and HDC 342 are energized only after disk drive 230 becomes operational (step 918). Preamp 332, read channel 341 and HDC 342 can be referred to as a storage circuit and include circuits to transform data stored on a storage device to a digital signal.

Fig. 7 is a schematic representation of memory 202. User data is first stored from location 724 to location 702 in a sequential manner in memory 202. In one embodiment, DSP/MPU 343 uses a pointer system in connection with memory 202 to determine when the amount of data stored the amount data stored reaches an upper threshold value (step 922). When the amount of data stored in memory 202 reaches the upper threshold value, HDC 342, read channel 341, preamp 332, disk drive 230 and VCM 334 are powered down or deenergized (step 924). Of course, as will be appreciated by one of ordinary skill in the art, while data is being to memory 202, data may also be read contemporaneously therefrom by DSP/MPU 343 for decompression and playback. Data is then read out from memory 202 starting at location 702 towards location 724 by DSP/MPU 343 (step 926). When the data file has been completely read from memory (step 928), the user can select another file. The data is continually read from memory 202, until the amount of data remaining is below a low threshold value

(step 930). When the data remaining in memory 202 is below the threshold value, disk drive 230, VCM 334, preamp 332, read channel 341 and HDC 342 are sequentially energized as noted above, and data is transferred from the storage device to memory 202.

Fig. 10, is an alternate embodiment to Fig. 9. Instead of utilizing a pointer system, the amount of data transferred to memory 202 is counted (step 1020) by a counter incorporated in DSP/MPU 343. The sequential energization of the disk drive 230, VCM 334, preamp 332, read channel 341 and HDC 342 is similar to that of the embodiment of Fig. 9 (steps 1012, 1014, 1016 and 1018). When amount of data transfer to memory 202 is greater than or equal to an upper limit U (step 1022), HDC 342, read channel 341, preamp 332, disk drive 230 and VCM 334 are powered down or deenergized (step 1024). As data is read from memory, the counter decrements the count, and when the count is less than or equal to a lower limit l (step 1030), disk drive 230, VCM 334, preamp 332, read channel 341 and HDC 342 are sequentially energized as noted above, and data is transferred from the storage device to memory 202.

Fig. 11 is another alternate embodiment to Fig. 9. The embodiment in Fig. 9 utilizes a timer incorporated in DSP/MPU 343 to approximate the amount of data transferred to memory 202 in accordance with the data transfer rate of disk drive 230. The sequential energization of disk drive 230, VCM 334, preamp 332, read channel 341 and HDC 342 is similar to that of the embodiment of Fig. 9 (steps 1112, 1114, 1116 and 1118). The timer is started (step 1119) as data is transferred form disk drive 230 to memory 202. When the timer times out, HDC 342, read channel 341, preamp 332, disk drive 230 and VCM 334 are powered down or deenergized (step 1124). As data is read from memory, the timer is started (1125), and when the timer times out (step 1130), disk drive 230, VCM 334, preamp 332, read channel 341 and HDC 342 are sequentially energized as noted above, and data is transferred from the storage device to memory 202.

In the simplest implementation, media data representing one selection (such as a single song) is transferred from disk drive 230 to memory 202 for playback. Fig. 8 is a schematic representation of memory 202, and Fig. 12 is a flow chart illustrating an alternate implementation. As shown therein, instead of retrieving just one selection, first portions of multiple selections are transferred from disk drive 230 to memory 202. These multiple selections may include the user's favorite selections, random selections from an external source, or the like (step 1204). When the user starts playing back the selection, a timer is started (step 1208) and the first selection is played back (step

1210). If a user instruction is received (step 1212) to continue playing that selection is received within a predetermined time (step 1214), the remaining portion of the selection is transferred from disk drive 230 to memory 202 (step 1216) for continued play back (step 1218). If the timer times out (step 1214), the first portion of the next selection (step 1206) is played back and the process is repeated for each remaining first portion. Alternatively, instead of using a timer, a memory threshold, as shown in Fig 8, may be utilized permit playback of the entire current selection if the user instruction is received before the memory being read out goes below the current selection threshold. Otherwise the first portion of the next selection is played back. Of course, the play back of portions of selections 1 through N may be in any order, such as sequential, random and predetermined. If the play back is in sequential order new selections may be transferred from disk drive 230 to memory 202 to replace previously played back selections.

Figs. 4 and 5 show a second embodiment of the present invention. The second embodiment is similar to the first embodiment except the second embodiment does not include memory 202. This embodiment media data is recorded thereon in a similar manner as the first embodiment and no further discussion is provided herein. For playback operation, the media data is retrieved directly from disk drive 230 for playback through output 216. The other portions of the playback operation are similar to the first embodiment. In the second embodiment disk drive 230 will be powered on any time media data is recorded or played back. As such this embodiment is particularly applicable when the power supply is external. For example the media player/recorder of the second embodiment may be a portable device used in an automobile supply by energy therefrom.

While the invention has been described in conjunction with several specific embodiments, it is evident to those skilled in the art that many further alternatives, modifications and variations will be apparent in light of the foregoing description. Thus, the invention described herein is intended to embrace all such alternatives, modifications, applications and variations as may fall within the spirit and scope of the appended claims.